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(54) **ACCOMMODATING INTRAOCULAR LENSES**

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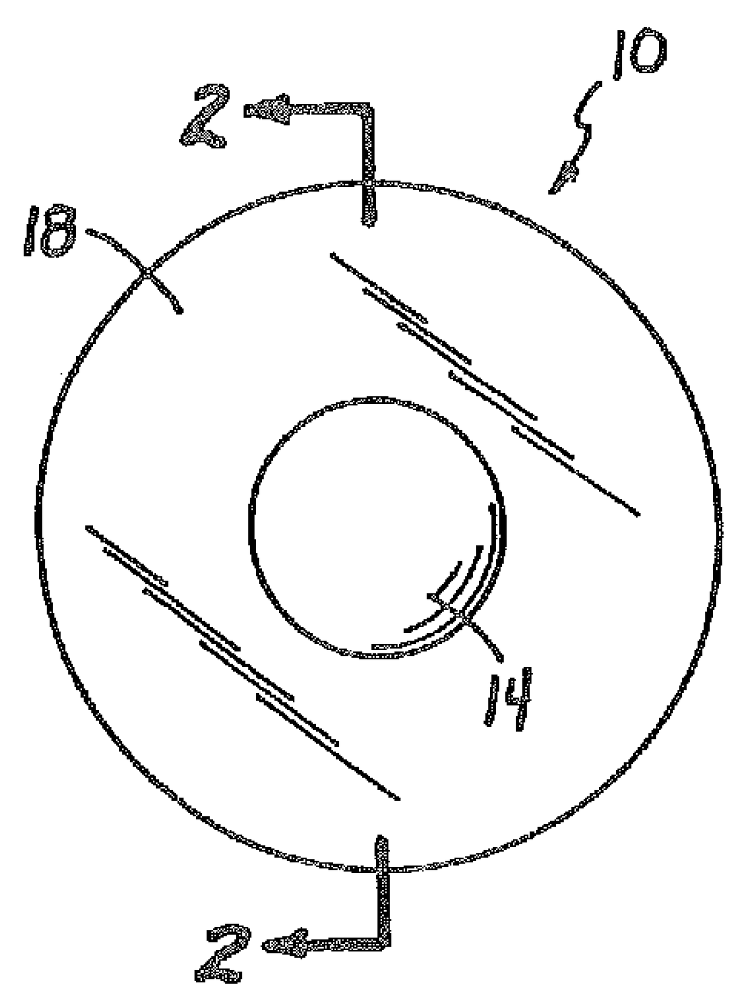
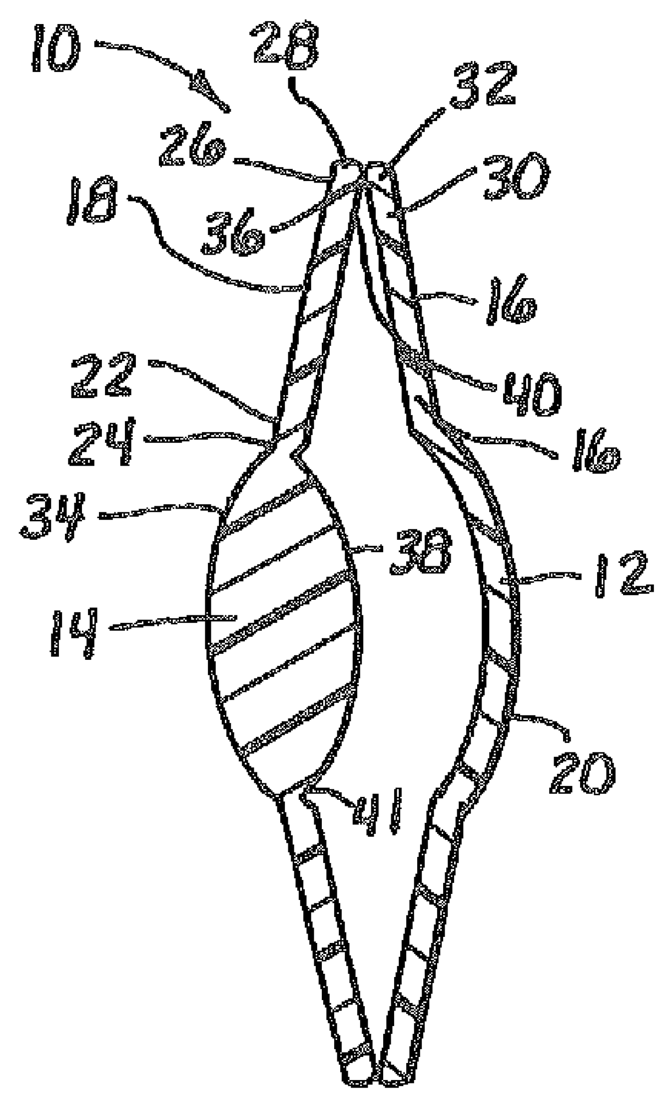
(57) **ABSTRACT**

Intraocular lenses for providing accommodation include an anterior optic, a posterior optic, and a lens structure. In one such lens, the lens structure comprises an anterior element coupled to the anterior optic and a posterior element coupled to the posterior optic. The anterior and posterior elements are coupled to one another at a peripheral region of the intraocular lens. The intraocular lens may also includes a projection extending anteriorly from the posterior element that limits posterior motion of the anterior optic so as to maintain a minimum separation between anterior optic and an anterior surface of the posterior optic.

5 Claims, 3 Drawing Sheets





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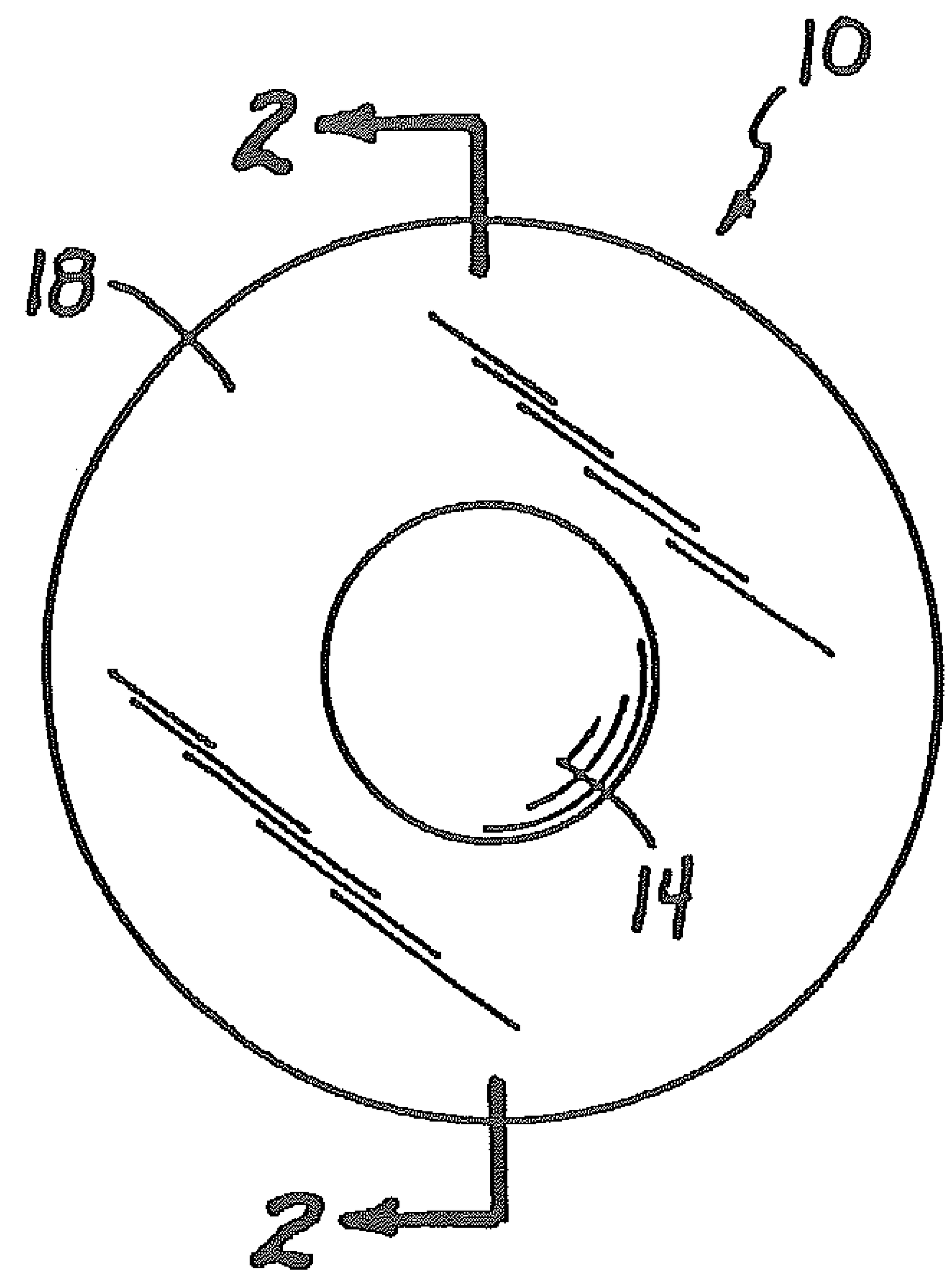

Fig. 1

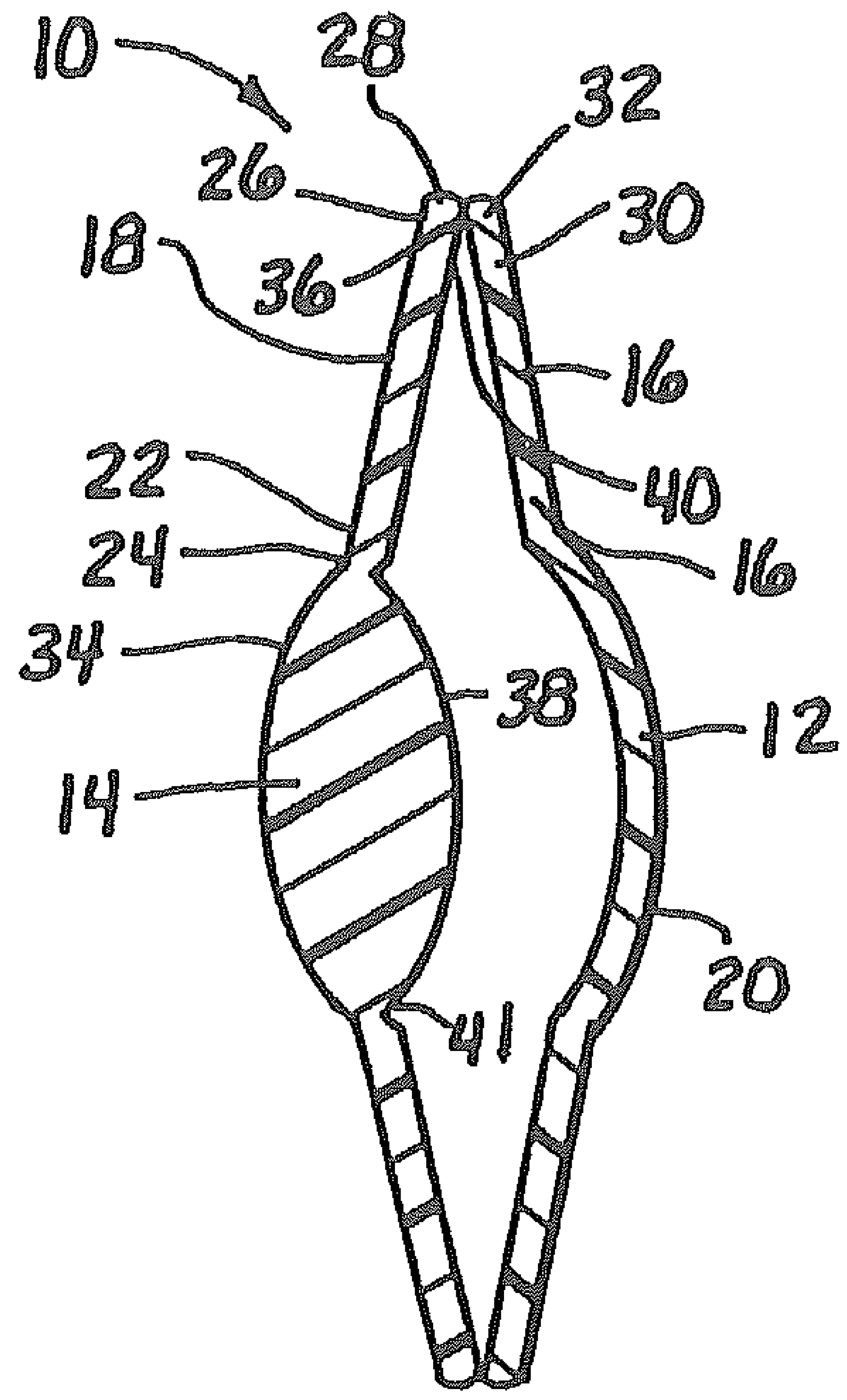

Fig. 2

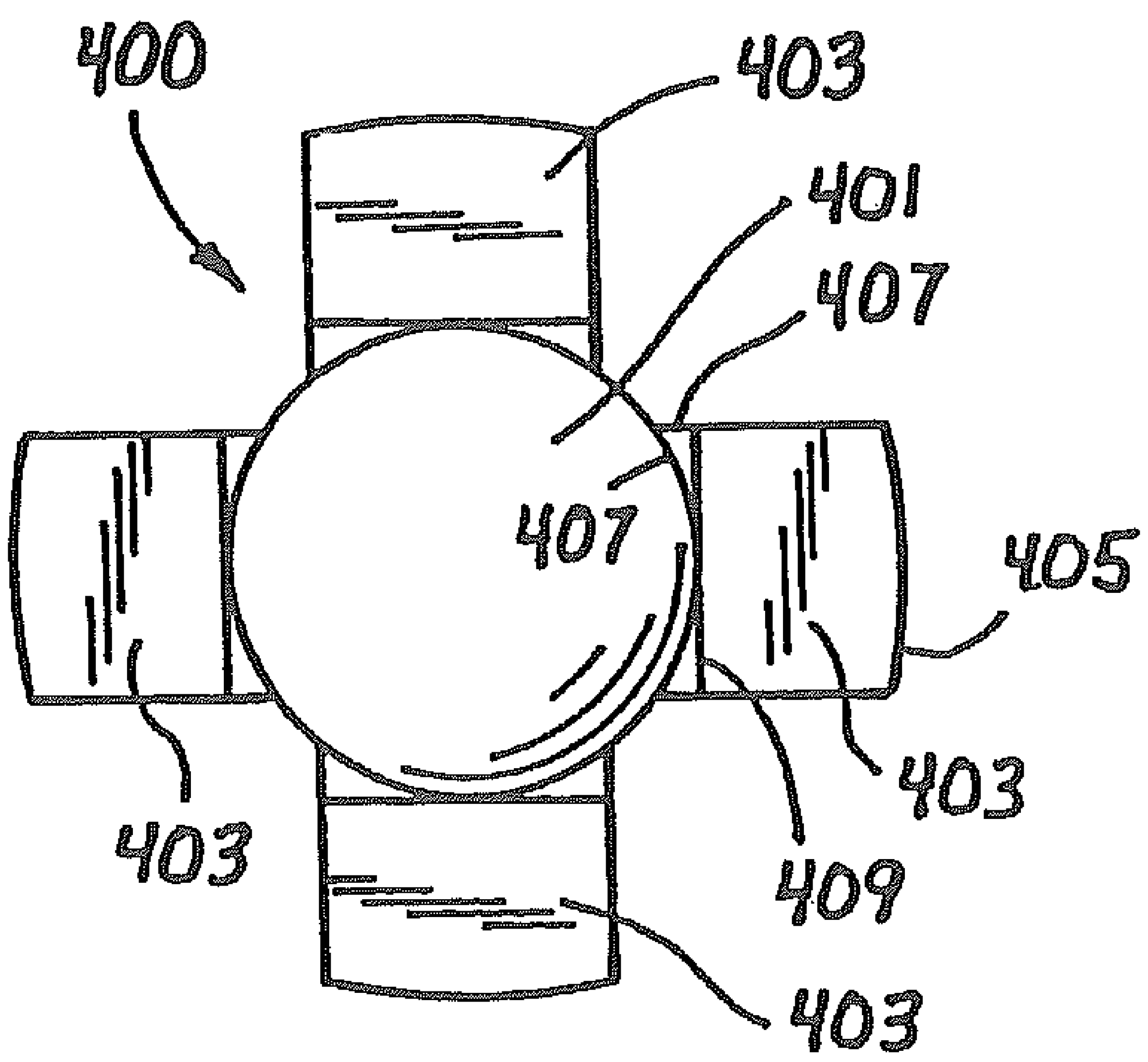

Fig. 6

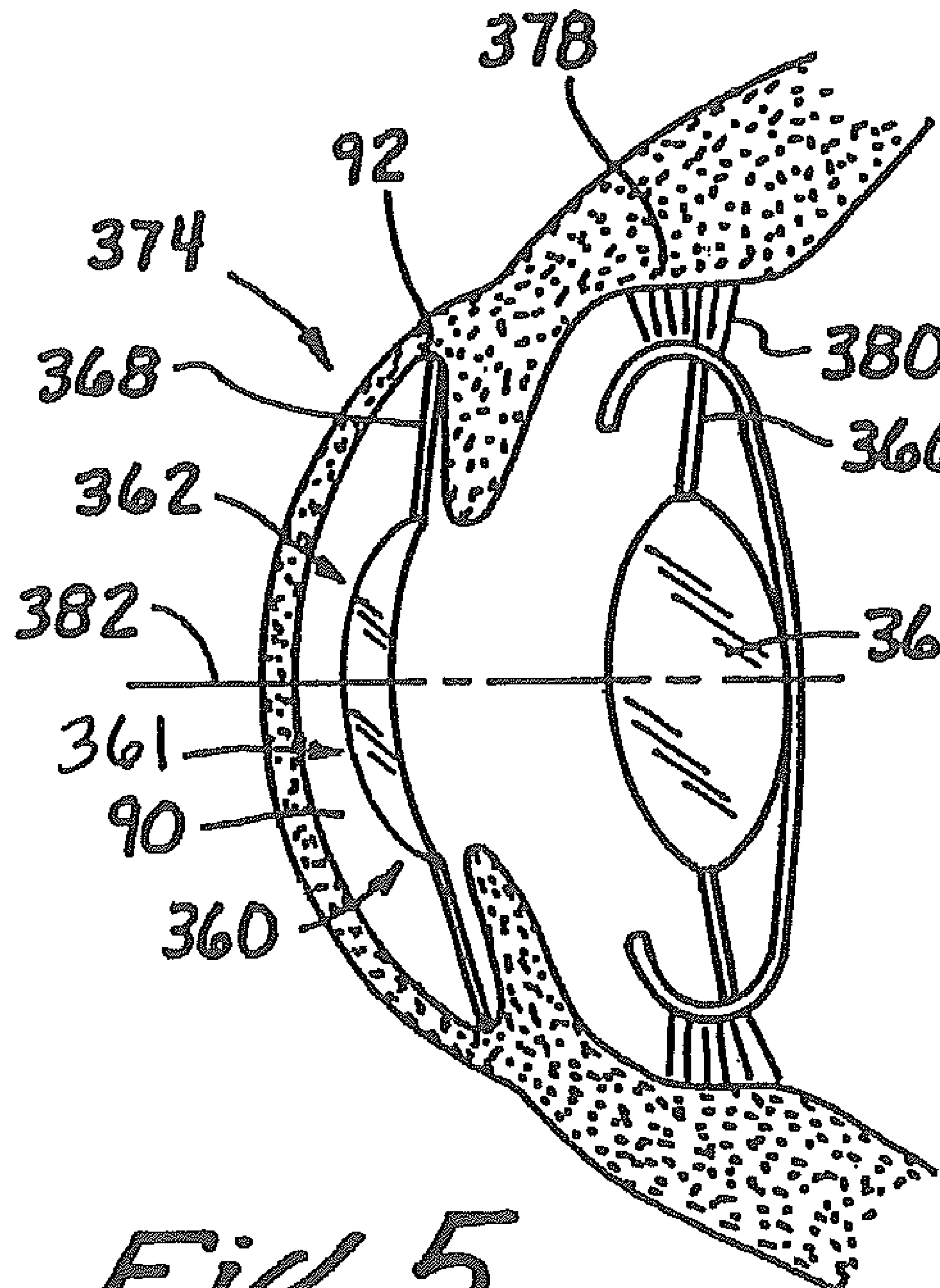

Fig. 5

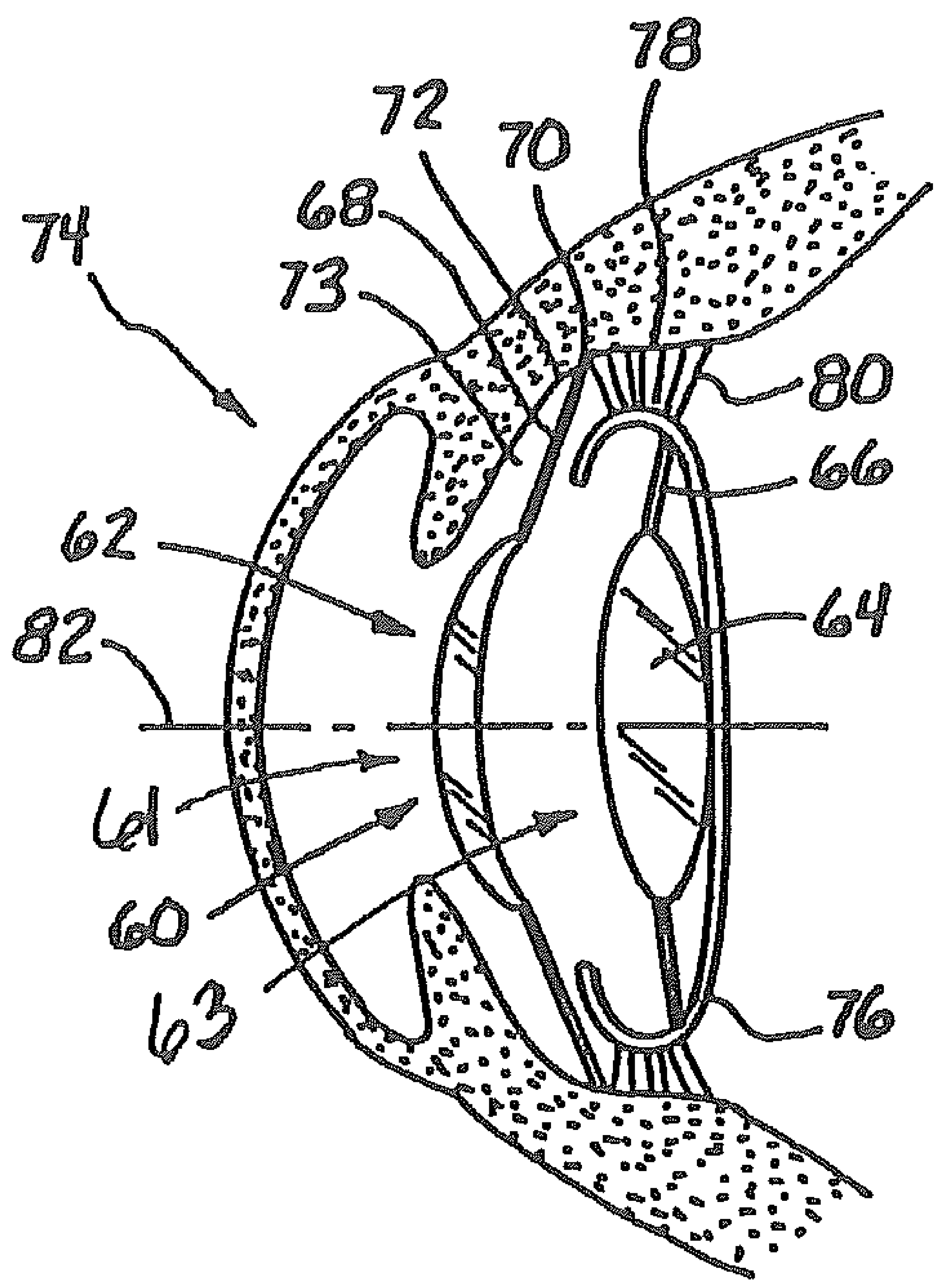
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Fig. 4

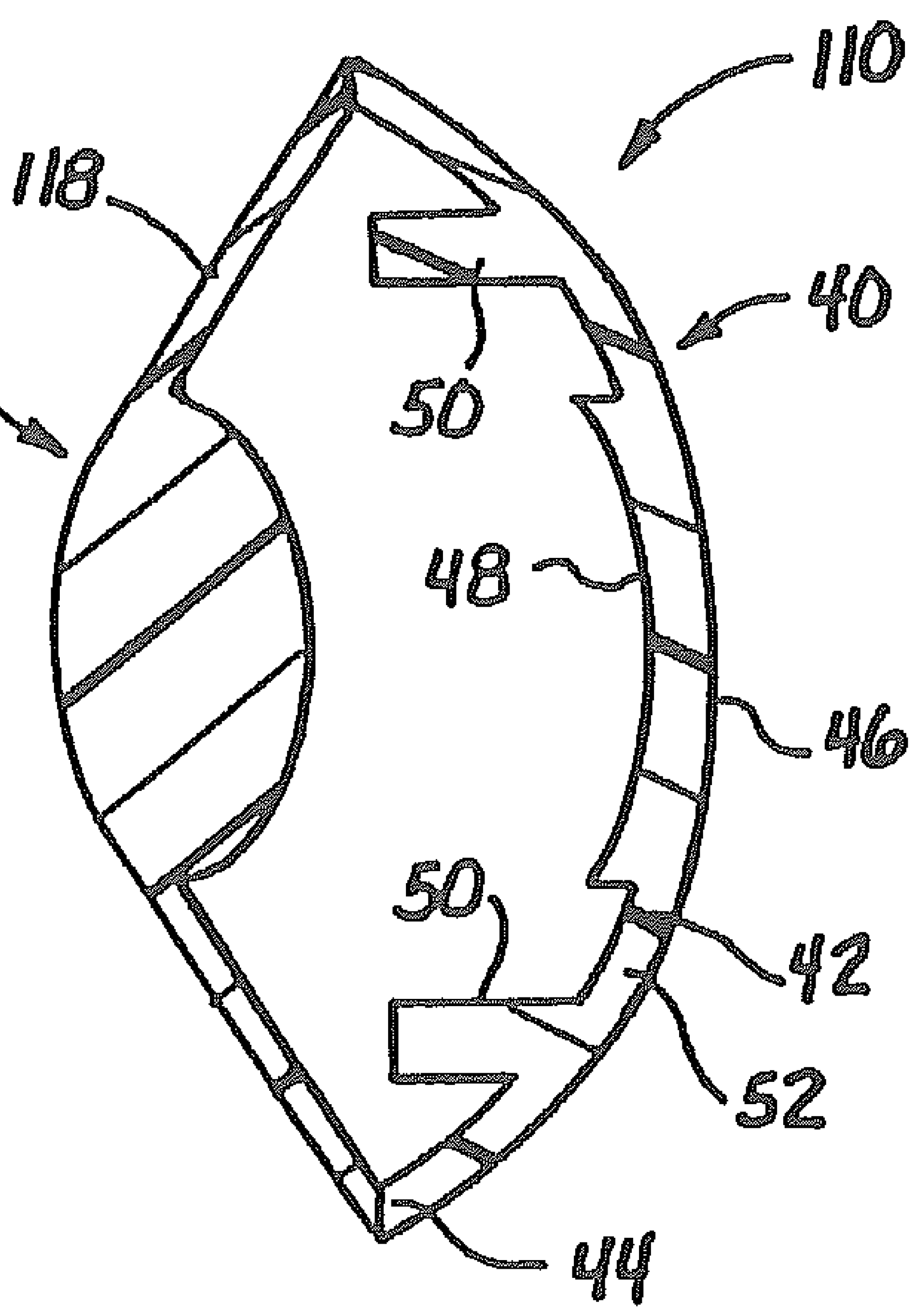
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Fig. 3

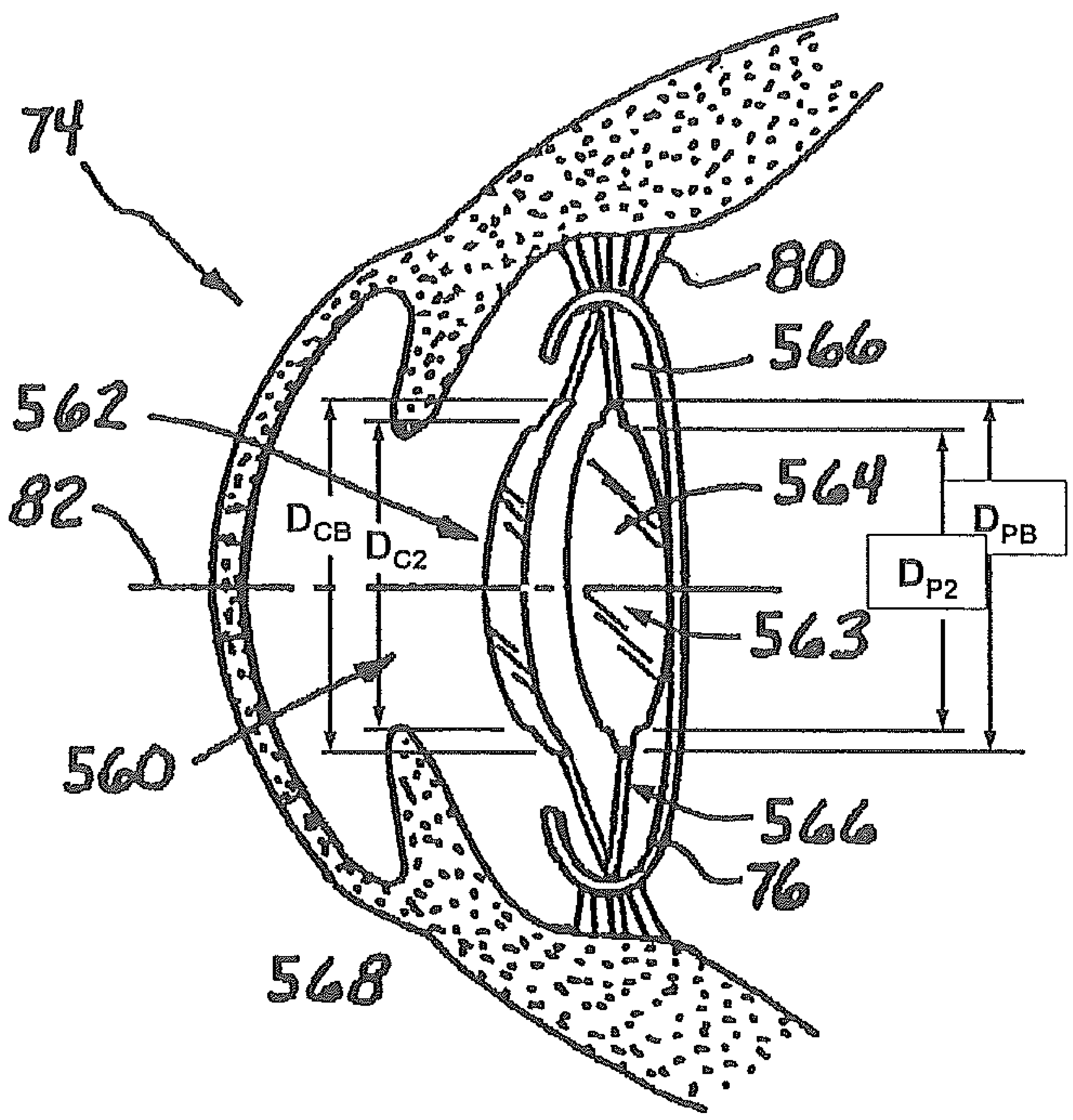

FIG. 7

ACCOMMODATING INTRAOCULAR LENSES

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation application of U.S. patent application Ser. No. 11/329,276, filed on Jan. 9, 2006, which is continuation application of U.S. patent application Ser. No. 10/234,801, filed on Sep. 4, 2002, now abandoned, which is a continuation-in-part application of U.S. patent application Ser. No. 09/390,380, filed Sep. 3, 1999, now U.S. Pat. No. 6,616,692, which claims the benefit of U.S. provisional application 60/132,085, filed Apr. 30, 1999, the entire contents of each of which applications are hereby incorporated by reference in their entirety for all purposes as if fully set forth herein.

BACKGROUND OF THE INVENTION

The present invention relates to intraocular lens combinations. More particularly, the invention relates to intraocular lens combinations which are adapted to provide substantial benefits, such as accommodating movement and/or inhibition of posterior capsule opacification (PCO) in the eye.

The human eye includes an anterior chamber between the cornea and iris, a posterior chamber including a capsular bag containing a crystalline lens, a ciliary muscle, a vitreous chamber behind the lens containing the vitreous humor, and a retina at the rear of this chamber. The human eye has a natural accommodation ability. The contraction and relaxation of the ciliary muscle provides the eye with near, intermediate and distant vision. This ciliary muscle action shapes the natural crystalline lens to the appropriate optical configuration for focusing light rays entering the eye on the retina.

After the natural crystalline lens is removed, for example, because of cataract or other condition, a conventional, monofocal IOL can be placed in the posterior chamber. Such a conventional IOL has very limited, if any, accommodating ability. However, the wearer of such an IOL continues to require the ability to view both near and far (distant) objects. Corrective spectacles may be employed as a useful solution. Recently, multifocal IOLs without accommodating movement have been used to provide near/far vision correction.

Attempts have been made to provide IOLs with accommodating movement along the optical axis of the eye as an alternative to shape changing. Examples of such attempts are set forth in Levy U.S. Pat. No. 4,409,691, U.S. Pat. Nos. 5,674,282 and 5,496,366 to Cumming, U.S. Pat. No. 6,176,878 to Gwon et al, U.S. Pat. No. 6,231,603 to Lang et al, and U.S. Pat. No. 6,406,494 to Laguette et al. The disclosure of each of these patents is incorporated herein by reference.

One problem that exists with such IOLs is that they often cannot move sufficiently to obtain the desired accommodation. The degree of accommodation has been closely related to the lens prescription of the individual patient. In addition, the presence of such lenses can result in cell growth from the capsular bag onto the optics of such lenses. Such cell growth, often referred to as posterior capsule opacification (PCO), can interfere with the clarity of the optic to the detriment of the lens wearer's vision.

It would be advantageous to provide IOLs adapted for accommodating movement, which can preferably achieve an acceptable amount of accommodation and/or a reduced risk of PCO.

SUMMARY OF THE INVENTION

New intraocular lens combinations (ILCs) have been disclosed. The present ILCs provide distance, near and intermediate vision through position, preferably axial position, changes in the eye. The present combinations preferably enhance the degree of accommodation achieved in spite of the movement and space limitations within the eye. One advantage of the present ILCs is the ability to standardize the prescription or optical power of the moving or accommodating lens of the ILC. Thus, the required amount of movement in the eye to achieve accommodation can be substantially the same for all patients. This greatly facilitates the design of the moving or accommodating lens. Further, with at least certain of the present ILCs, inhibition of PCO is obtained. The present ILCs are relatively straightforward in construction, can be implanted or inserted into the eye using systems and procedures which are well known in the art and function effectively with little or no additional treatments or medications being required.

In one broad aspect of the present invention, intraocular lens combinations (ILCs) comprise a first optic body, second optic body and a movement assembly. The first optic body has a negative or plano optical power and is adapted to be placed in a substantially fixed position in a mammalian eye. In those cases where the first optic body has a negative optical power, it is also called the compensating optic body. The second optic body, also called the primary optic body, has a higher optical power than the first optic body. The movement assembly is coupled to the second optic body and is adapted to cooperate with the eye, for example, the zonules, ciliary muscle and capsular bag of the eye, to effect accommodating movement of the second optic body in the eye.

Advantageously, the second optic body has a high plus optical power to reduce the amount of movement, for example, axial movement, in the eye needed to provide accommodation for intermediate and near vision. The negative or minus optical power of the first optic body compensates for the excess plus or positive optical power in the first optic body. The use of such a compensating lens, that is the first optic body having a negative optical power, can allow for standardization of the optical power correction in the second optic body. In other words, the optical power of the second optic body, that is the primary or movable optic body, can be approximately equal from optic body to optic body, while the optical power of the first optic body, that is the compensating or fixed optic body, is adjusted from optic body to optic body to meet the specific vision correction needs (prescription) of each individual patient. Consequently, the required amount of movement of the second optic body in the eye can be approximately the same for all patients.

The present ILCs provide accommodation, preferably an acceptable degree of accommodation, in spite of movement and space limitations in the eye. For example, the maximum theoretical amount of axial movement for a simple disc lens having an overall diameter of 11 millimeters (mm) and an optic diameter of 5 mm that undergoes 1 mm of compression in its diameter is about 1.65 mm. The amount of axial movement required for a plus 15 diopter optic to provide 2.5 diopters of additional power in the spectacle plane is about 2.6 mm. However, a plus 30 diopter optic requires only 1.2 mm of axial movement to provide 2.5 diopters of additional power in the spectacle plane. Thus, by increasing the plus power of the second optic, which is adapted for accommodating movement, a reduced amount of movement is needed to achieve higher or enhanced degrees of accommodation. The first or fixed optic preferably has a minus power to compensate for the excess plus power in the second optic.

The present ILCs preferably include first and second optics with optical powers which provide a net plus optical power. To illustrate, assume that the patient requires a plus 15 diopter correction. The first optic body is provided with a minus 15 diopter optical power and the second optic body with a plus 30 diopter optical power. The net optical power of this ILC is approximately the sum of minus 15 diopters and plus 30 diopters or plus 15 diopters, the desired prescription for the patient in question. The powers of the first and second optics are only approximately additive since the net power of the combination also depends on other factors including, but not limited to, the separation of the two optics, the magnitude of the power of each individual optic body and its location in the eye and the like factors. Also, by adjusting the optical power of the first optic body, the net optical power of the ILC can be adjusted or controlled even though the optical power of the second optic body is standardized or remains the same, for example, at a plus 30 diopter optical power. By standardizing the optical power of the second optic body, the amount of movement in the eye required to obtain a given level of accommodation is substantially the same, and preferably well within the space limitations in the eye, from patient to patient.

In one very useful embodiment, the movement assembly comprises a member including a proximal end region coupled to the second optic body and a distal end region extending away from the second optic body and adapted to contact a capsular bag of the eye. Such movement assembly may completely circumscribe the second optic body or may be such as to only partially circumscribe the second optic body.

The second optic body preferably is adapted to be positioned in the capsular bag of the eye.

The first optic body may be coupled to a fixation member, or a plurality of fixation members, adapted to assist in fixating the first optic body in the eye. Each fixation member preferably has a distal end portion extending away from the first optic body. In one embodiment, the distal end portion of the fixation member is adapted to be located in the capsular bag of the eye. Alternately, the distal end portion of the fixation member may be located in contact with a sulcus of the eye. As a further alternate, the distal end portion of the fixation member may be adapted to be located in an anterior chamber of the eye.

The first optic body may be located posterior in the eye relative to the second optic body or anterior in the eye relative to the second optic body. In a useful embodiment, the first optic body is adapted to be positioned in contact with the posterior wall of the capsular bag of the eye. This positioning of the first optic body provides for effective compensation of the plus or positive vision correction power of the second optic body. In addition, by having the first optic body in contact with the posterior wall of the capsular bag, cell growth from the capsular bag onto the ILC, and in particular onto the first and second optics of the ILC, is reduced. This, in turn, reduces the risk of or inhibits posterior capsule opacification (PCO).

In one embodiment, the fixation member or members and the movement assembly are secured together, preferably permanently secured together. Thus, when inserting the ILC into the eye, a single combined structure can be inserted. This reduces the need to position the first and second optics relative to each other. Put another way, this feature allows the surgeon to very effectively and conveniently position the ILC in the eye with reduced surgical trauma to the patient.

The fixation member and movement assembly may be secured, for example, fused, together at the distal end portion of the fixation member and the distal end region of the movement assembly.

In an alternate embodiment, there is no connection between the fixation member or members of the compensating lens and the movement assembly of the primary lens. That is, the compensating lens and primary lens are completely separate from and independent of one another, enabling them to be implanted consecutively, rather than simultaneously. This allows the lenses to be inserted through a smaller incision than would be possible with a combined structure. In the case of separate lenses, however, special care must be taken to axially align the two lenses in order to avoid decentration issues.

In another broad aspect of the present invention, ILCs are provided which comprise a first optic body having a posterior surface adapted to be positioned in contact with a posterior wall of the capsular bag of the eye; a second optic body adapted to focus light toward a retina of the eye; and a movement assembly coupled to the second optic body and adapted to cooperate with the eye to effect accommodating movement of the second optic body in the eye. The first optic body has a substantially plano optical power or a negative optical power. These ILCs are particularly adapted to inhibit PCO.

The first optic body of these combinations preferably is adapted to be placed in a substantially fixed position in the eye. The posterior surface of the first optic body advantageously is configured to substantially conform to a major portion, that is, at least about 50%, of the posterior wall of the capsular bag of the eye in which the combination is placed. More preferably, the posterior surface of the first optic body is configured to substantially conform to substantially all of the posterior wall of the capsular bag. Such configuration of the first optic body is very useful in inhibiting cell growth from the eye onto the first and second optics and in inhibiting PCO.

In one embodiment, the first optic body, which contacts the posterior wall of the capsular, has a substantially plano optical power and the second optic body has a far vision correction power. In an alternate embodiment, the first optic body has a negative optical power and the second optic body has a positive optical power, more preferably, so that the optical powers of the first and second optics provide a net plus optical power in the eye in which the combination is placed. In this latter embodiment, the second, or primary, optic body is preferably placed in the capsular bag, while the first, or compensating, optic body, may be placed in the bag, the sulcus or the anterior chamber, or attached to the iris.

In a very useful embodiment, the first optic body includes an anterior surface and at least one projection extending anteriorly from this anterior surface. The at least one projection is positioned to limit the posterior movement of the second optic body in the eye. Thus, the movement of the second optic body is effectively controlled to substantially maintain the configuration of the combination and/or to substantially maintain an advantageous spacing between the first and second optics.

The movement assembly may be structured and functions similarly to movement assembly of the previously described ILCs.

The first optic body may have a fixation member or members coupled thereto. The fixation member or members are adapted to assist in fixating the first optic body in the eye, that is in contact with the posterior wall of the capsular bag of the eye. In one embodiment, the first optic body itself is configured and/or structured so that no fixation member or members are needed to maintain the first optic body in contact with the posterior wall of the capsular bag of the eye. The first optic body and the movement assembly of these ILCs may be secured together.

In general, the first and second optics of the present ILCs may be made of any suitable materials. Preferably, the first and second optics are made of polymeric materials. More preferably, the first and second optics and the movement assembly, and the fixation member(s), if any, are deformable for insertion through a small incision in the eye.

The present movement assemblies are sufficiently flexible to facilitate movement of the second optic body in the eye upon being acted upon by the eye. In one very useful embodiment, the movement assembly includes a hinge assembly, preferably adapted and positioned to facilitate the accommodating movement of the second optic body.

In those embodiments in which the first optic body has a substantially plano optic body power, the second optic body preferably has a far vision correction power, more preferably such a power for infinity, in the unaccommodated state.

In a further broad aspect of the present invention, methods for inserting an ILC in an eye are provided. Such methods comprise providing an ILC in accordance with the present invention, as described herein. The ILC is placed into the eye, for example, in the capsular bag of the eye or partly in the capsular bag of the eye, using equipment and techniques which are conventional and well known in the art. The ILC is placed in a rest position in the eye, for example, a position so that the eye, and in particular the ciliary muscle and zonules of the eye, effectively cooperate with the movement assembly to move the second optic body of the ILC anteriorly in the eye from the rest position to provide for positive accommodation. No treatments or medications, for example, to paralyze the ciliary muscle, to facilitate fibrosis or otherwise influence the position of the ILC in the eye, are required.

In one embodiment, the primary and compensating lenses are connected by the fixation member or members and the movement assembly, and are thus simultaneously implanted in the eye. In another embodiment, the primary lens is implanted first and centered about the optical axis. The the compensating lens is then inserted anteriorly of the primary lens and optically aligned with the primary lens. This latter embodiment may require a smaller incision than that required for the unitary combination of the former embodiment. In addition, this embodiment allows for refractive measurements to be made after the primary lens has been implanted, so that any new refractive errors that may have been introduced as a result of the surgery itself can be taken into account, and a more accurate prescription for the compensating lens can be obtained.

Preferably, the first and second optics and the movement assembly are deformed prior to being placed into the eye. Once the ILC is placed in the eye, and after a normal period of recovery from the surgical procedure, the ILC, in combination with the eye, provides the mammal or human wearing the ILC with effective accommodation, preferably with reduced risk of PCO. In the unaccommodated state, the ILC preferably provides the mammal or human wearing the ILC with far vision correction.

In another broad aspect of the of the present invention, an intraocular lens comprises an anterior optic, a posterior optic, and a lens structure. The lens structure comprises an anterior element coupled to the anterior optic and a posterior element coupled to the posterior optic. The anterior and posterior elements are coupled to one another at a peripheral region of the intraocular lens. The intraocular lens also includes a projection extending anteriorly from the posterior element that limits posterior motion of the anterior optic so as to maintain a minimum separation between anterior optic and an anterior surface of the posterior optic.

Any and all features described herein and combinations of such features are included within the scope of the present invention provided that the features of any such combination are not mutually inconsistent.

Further aspects and advantages of the present invention are set forth in the following detailed description and claims, particularly when considered in conjunction with the accompanying drawings in which like parts bear like reference numerals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front plan view of an ILC in accordance with the present invention.

FIG. **2** is a cross-sectional view taken generally along line **2-2** of FIG. **1**.

FIG. **3** is a cross-sectional view of an additional ILC in accordance with the present invention.

FIG. **4** is a fragmentary sectional view of an eye in which an alternate ILC in accordance with the present invention has been implanted.

FIG. **5** is a fragmentary sectional view, similar to FIG. **4**, in which the compensating optic body of the ILC is implanted in the anterior chamber of the eye.

FIG. **6** is a front plan view of an intraocular lens useful in an ILC in accordance with the present invention.

FIG. **7** is a fragmentary sectional view, similar to FIGS. **4** and **5**, in which the compensating optic body of the ILC is implanted in the capsular bag of the eye.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to FIGS. **1** and **2**, an ILC according to the present invention, shown generally at **10**, includes a first optic body **12**, a second optic body **14**, a disc type fixation member **16** and a disc type movement assembly **18**.

The first optic body **12** has substantially plano optical power and is adapted to be held in a fixed position, for example, at least partially by the fixation member **16**. When the ILC **10** is positioned in a human eye, the posterior surface **20** of first optic body **12** is in contact with the inner posterior wall of the capsular bag of the eye. This positioning of optic body **12** is very effective in reducing or inhibiting endothelial cell growth from the capsular bag onto the first optic body **12**. In effect, the positioning of the first optic body **12** against the posterior surface of the capsular bag inhibits or reduce the risk of PCO.

The second optic body **14** includes a distance vision correction power. The movement assembly **18** extends radially outwardly from second optic body **14** and fully circumscribes the second optic body **14**. Movement assembly **18** has a proximal end region **22** which is coupled to the second optic body **14** at first optic body periphery **24**.

Movement assembly **18** extends radially outwardly to a distal end region **26** including a peripheral zone **28**.

Fixation member **16** includes a distal end portion **30** including a peripheral area **32**. The movement assembly **18** and fixation member **16** are fused together at the peripheral zone **28** and peripheral area **32**. Thus, the entire ILC **10** is a single unitary structure. The first optic body **12** and fixation member **16** can be manufactured separately from second optic body **14** and movement assembly **18** and, after such separate manufacture, the fixation member and movement assembly can be fused together. Alternately, the entire ILC **10** can be manufactured together. Also, if desired, the first optic body **12** and fixation member **16** can be inserted into the eye separately from the second optic body **14** and movement assembly **18**. Thus, ILC **10** can comprise a plurality of separate components.

Movement assembly **18** extends outwardly from second optic body **14** sufficiently so that the distal end region **26**, and in particular the peripheral zone **28** of the distal end region, is in contact with the inner peripheral wall of the posterior capsular bag when the ILC **10** is implanted in the eye.

As best seen in FIG. **2**, when ILC **10** is at rest, the second optic body **14** is positioned vaulted anteriorly relative to the distal end region **26** of movement assembly **18**. In other words, the anterior surface **34** of second optic body **14** is anterior of the anterior surface **36** of movement assembly **18** at distal end region **26** and/or the posterior surface **38** of the second optic body **14** is anterior of the posterior surface **40** of the movement assembly at the distal end region.

The first and second optics **12** and **14** may be constructed of rigid biocompatible materials, such as polymethyl methacrylate (PMMA), or flexible, deformable materials, such as silicone polymeric materials, acrylic polymeric materials, hydrogel polymeric materials, and the like, which enable the optics **12** and **14** to be rolled or folded for insertion through a small incision into the eye. Although the first and second optics **12** and **14** as shown are refractive lens bodies, the present ILCs can include at least one diffractive lens body, and such embodiment is included within the scope of the present invention.

As noted previously, first optic body **12** has a substantially plano or zero optical power. Second optic body **14** is prescribed for the wearer of ILC **10** with a baseline or far (distance) diopter power for infinity. Thus, the wearer of ILC **10** is provided with the vision correction power of second optic body **14** with little or no contribution from the first optic body **12**.

The fixation member **16** and movement assembly **18**, as shown, are integral (unitary) with and circumscribe the first and second optics **12** and **14**, respectively. Alternately, fixation member **16** and/or movement assembly **18** can be mechanically or otherwise physically coupled to first optic body **12** and second optic body **14**, respectively. Also, the fixation member **16** and/or movement assembly **18** may only partially circumscribe first and second optics **12** and **14**, respectively, and such embodiments are included within the scope of the present invention. The fixation member **16** and movement assembly **18** may be constructed from the same or different biocompatible materials as first and second optics **12** and **14**, and preferably are made of polymeric materials, such as polypropylene silicone polymeric materials, acrylic polymeric materials, and the like. Movement assembly **18** has sufficient strength and rigidity to be effective to transfer the force from the ciliary muscle of the eye so that the second optic body **14** is movable axially in the eye to effect accommodation.

Movement member **18** includes a region of reduced thickness **41** located at the proximal end region **22**. This area of reduced thickness, which completely circumscribes the second optic body **14**, acts as a hinge to provide additional flexibility to the movement member **18** to extenuate or amplify the accommodating movement of second optic body **14** in response to the action of the ciliary muscle and zonules.

The fixation member **16** and movement assembly **18** preferably are deformable, in much the same manner as first and second optics **12** and **14** are deformable, to facilitate passing ILC **10** through a small incision into the eye. The material or materials of construction from which fixation member **16** and movement assembly **18** are made are chosen to provide such members with the desired mechanical properties, e.g., strength and/or deformability, to meet the needs of the particular application involved.

The ILC **10** can be inserted into the capsular bag of a mammalian eye using conventional equipment and techniques, for example, after the natural crystalline lens of the eye is removed, such as by using a phacoemulsification technique. The ILC **10** preferably is rolled or folded prior to insertion into the eye, and is inserted through a small incision into the eye and is located in the capsular bag of the eye.

The ILC **10** in the eye is located in a position in the capsular bag so that the posterior surface **20** of first optic body **12** is maintained in contact with the inner posterior wall of the capsular bag. As noted previously, positioning the first optic body **12** in contact with the posterior wall of the capsular bag reduces the risk of or inhibits cell growth from the capsular bag onto the first optic body **12** which, in turn, reduces or inhibits PCO. The ciliary muscle and zonules of the eye provide force sufficient to move axially second optic body **14** sufficiently to provide accommodation to the wearer of ILC **10**.

The ILC **10** should be sized to facilitate the movement of the second optic body **14** in response to the action of the ciliary muscle and zonules of the eye in which the ILC is placed.

If the ILC **10** is too large, the ciliary muscle and zonules will be inhibited from effectively contracting/relaxing so that the amount of accommodating movement will be unduly restricted. Of course, if the ILC **10** is too small, the second optic body **14** will be ineffective to focus light on the retina of the eye, may cause glare and/or the movement member may not cooperate with the eye to effect the desired amount of accommodating movement. If the ILC **10** is to be included in an adult human eye, the first and second optics **12** and **14** preferably have diameters in the range of about 3.5 mm to about 7 mm, more preferably in the range of about 5 mm to about 6 mm. The ILC **10** preferably has an overall maximum diameter, with the movement assembly **18** in the unflexed or rest state, in the range of about 8 mm to about 11 mm or about 12 mm.

The present ILC **10** has the ability, in cooperation with the eye, to move the second optic body **14** both posteriorly and anteriorly in the eye, to provide for both distance focus and near focus, respectively. This movement of ILC **10** advantageously occurs in response to action of the ciliary muscle and zonules, which action is substantially similar to that which effects accommodation in an eye having a natural crystalline lens. Thus, the ciliary muscle and zonules require little, if any, retraining to function in accordance with the present invention. The movement member **18**, as described herein, preferably is effective to facilitate or even enhance or extenuate the axial movement of the second optic body **14** caused by the action of the ciliary muscle and zonules to provide increased degree of accommodation.

FIG. **3** illustrates an additional ILC, shown generally at **110**, in accordance with the present invention. Except as expressly described herein, ILC **110** is structured and functions similar to ILC **10**. Components of ILC **110** which correspond to components of ILC **10** are indicated by the same reference numeral increased by 100.

One primary difference between ILC **110** and ILC **10** relates to the substitution of a posterior lens structure **40** for the first optic body **12** and fixation member **16**. Lens structure **40** includes a posterior face **42** which is configured to come in contact with and substantially conform to the inner posterior surface of the capsular bag of the eye in which the ILC **110** is to be placed. Thus, the surface **42** which extends around the peripheral area **44** and across the center region **46** of the lens structure **40** is adapted to come in contact with and substantially conform to the inner posterior wall of the capsular bag. Moreover, the lens structure **40** is adapted to remain in contact with this inner posterior wall of the capsular bag and to be fixed in the eye. This configuration has been found to be very effective in inhibiting cell growth from the eye onto the ILC **110**. The anterior surface **48** of lens structure **40** is configured to provide the lens structure with a substantially plano or zero optical power. Second optic body **114** is prescribed for the wearer of ILC **110** with a baseline or distance or far (distance) dioptic power for infinity. Thus, the wearer of ILC **110** is provided with a vision correction power of second optic body **114** with little or no contribution from the lens structure **40**.

Alternately, second optic body **114** has a high plus power, for example, plus 30 diopters. The lens structure **40**, and in particular the region of the lens structure, defined by the anterior surface **48**, which extends substantially across the entire field of vision of the wearer of ILC **110**, has a minus vision correction power which is controlled to provide the correction prescription for use in the eye in which the ILC **110** is placed. For example, if this eye requires a plus 15 diopter power, the lens structure **40** has a vision correction power of approximately minus 15 diopters so that the net vision correction power of the combination of lens structure **40** and second optic body **114**, is plus 15 diopters.

The lens structure can be made from materials described previously with regard to first optic body **12** and fixation member **16**.

One additional feature of lens structure **40** relates to the anteriorly extending projections **50** which extend from the base element **52** of lens structure **40**. The number of these projections **50** can range from 2 to about 6 or more. Alternately, a continuous annulus projecting anteriorly can be provided. The purpose of the projections **50** or the continuous annulus is to limit the posterior movement of the second optic body **114** and movement assembly **118**. This limitation in the movement provides an additional degree of control of the ILC **110**, and prevent a collapse of the ILC **110** and maintains an advantageous degree of separation between second optic body **114** and anterior surface **48** of lens structure **40**.

FIG. **4** illustrates the use of an alternate ILC in accordance with the present invention. This ILC, shown generally at **60** includes a compensating IOL **61** comprising a first, or compensating, optic body **62**, and a primary IOL **63** comprising a second, or primary, optic body **64** and a movement assembly **66**. The compensating optic body **62** is coupled to a fixation member **68** which includes a distal end portion **70** in contact with the periphery **72** of the sulcus **73** of eye **74**. Fixation member **68** is a disk fixation member which completely circumscribes the compensating optic body **62**. However, it should be noted that the disc fixation member **68** can be replaced by two or more filament fixation members or plate fixation members or other types of fixation members, many of which are conventional and well known in the art. Movement assembly **66** is coupled to the primary optic body **64** and completely circumscribes the primary optic body. The primary optic body **64** is located in the capsular bag **76** of eye **74** and is vaulted anteriorly to some extent to enhance accommodating movement of the primary optic body.

The primary optic body **64** has a plus power higher than the power required by the basic prescription of a presbyopic patient. For instance for a patient requiring plus 15 diopters of far vision correction, primary optic body **64** might have a corrective power of plus 30 diopters. The compensating optic body **62** is a negative or minus lens having a minus vision correction power which is controlled to provide the correct prescription for use in eye **74**. For the patient described above, the compensating optic body **62** has a vision correction power of approximately minus 15 diopters so that the net vision correction power of the combination of compensating optic body **62** and primary optic body **64** equals the patient's basic prescription of plus 15 diopters. The compensating optic body **62**, fixation member **68**, primary optic body **64** and movement assembly **66** can be made from materials described previously with regard to the first optic body **12**, fixation member **16**, second optic body **14** and movement assembly **18**, respectively.

The compensating optic body **62** is shown here as a meniscus style optic body; that is, the anterior surface of the optic body is convex and the posterior surface is concave. However, other negative diopter configurations could also be used, such as plano/concave or biconcave. In addition, one or both of the surfaces of the compensating optic body **62** could be multifocal or aspheric to allow for additional accommodation.

In the configuration shown in FIG. **4**, the fixation member **68** is in contact with the periphery **72** of the sulcus **73** of the eye **74**. This is a relatively durable component of the eye and is effective to support the fixation member **68** in maintaining the compensating optic body **62** in a fixed position.

The movement assembly **66** cooperates with the ciliary muscle **78** and zonules **80** of eye **74** to move the second optic body **64** axially along optical axis **82** of the eye. The amount of axial movement achieved will vary from patient to patient depending on such parameters as capsular bag dimensions. However, the movement should be at least about 0.5 mm, and more preferably, at least about 0.75 mm In a very useful embodiment, the accommodation assembly should allow about 1 mm to about 1.2 mm of movement. With a primary optic body **64** having a corrective power of plus 30 diopters, this amount of movement will be amplified to create an additional add power, or diopter shift, of about 1.75 to about 2.5, or possibly as high as 3.5 diopters. A diopter shift in this range is consistent with the near vision, or add, prescription of a "typical" presbyopic patient.

FIG. **5** illustrates another ILC, shown generally at **360**, in accordance with the present invention. Except as expressly described herein, ILC **360** is structured and functions similarly to ILC **60**. Components of ILC **360** which correspond to components of ILC **60** are identified by the same reference numeral increased by **300**.

One primary difference between ILC **360** and ILC **60** relates to the positioning of compensating optic body **362**. Specifically, compensating IOL **361** is located in anterior chamber **90** of eye **374**. Fixation member **368** is coupled to the compensating optic body **362** and extends outwardly and comes in contact with the angle **92** of eye **374**. The arrangement of compensating optic body **362** and fixation member **368** is such that the compensating optic body is maintained in a substantially stationary position in the anterior chamber **90** of eye **374**. The primary optic body **364** is adapted to be moved axially along optical axis **382** of eye **374** by the ciliary muscle **378** and zonules **380** acting on the movement assembly **366**.

Still another embodiment of an ILC according to the present invention is shown in FIG. **7**, indicated generally at **560**. Except as expressly described herein, ILC **560** is structured and functions similarly to ILC **60**. Components of ILC **560** which correspond to components of ILC **60** are identified by the same reference numeral increased by **500**.

Again, ILC **560** differs from ILC **60** primarily in the location of the compensating IOL **561**, which is located in the capsular bag **76** with the primary optic body **564**, rather than in the sulcus or anterior chamber. In this configuration, the compensating optic body **562** would not be truly stationary since the capsular bag **76** itself typically moves about 0.4 mm during accommodation. However, axial movement of the compensating optic body **562** relative the capsular bag **76** can be limited by appropriate design of the fixation member or members **568**. Controlling other factors such as material selection, length, width and angulation of the fixation member or members **58** relative the compensating optic body **562** can limit the overall axial movement of the compensating optic body **562** to less than 0.5 mm which, for the purposes of this invention, can be regarded as "substantially fixed."

A preferred method of implanting an ILC will now be discussed. The method is equally effective for the embodiments of FIGS. **5**, **6**, and **7**, but for purposes of illustration will be discussed specifically with reference to FIG. **7**.

Initially, the primary IOL **563** is inserted through an incision in the patient's cornea and positioned in the capsular bag **76** using conventional techniques. Preferably, the incision is less than 4 mm in length. If the primary optic body **564** and movement assembly **566** are unitary as illustrated, they are inserted simultaneously. However, it is also possible to implant an independent movement assembly **566** first, and then insert the primary optic body in the movement assembly **566**.

After the primary IOL **563** is placed in the capsular bag **76**, a measurement is taken to determine the location of the primary optic body **564** relative to the optical axis **82**. If desired, refractive measurements may also be made at this time to accurately determine an appropriate prescription for the compensating IOL **561**.

If the original incision is still open, the compensating IOL **561** is inserted through the same incision using conventional techniques. If the incision has closed, a new one, preferably also measuring less than 4 mm, is made before insertion. A keratoscope or similar instrument is then used to guide the surgeon in positioning the fixation member or members **568** such that compensating optic body **562** and the primary optic body **564** are axially aligned with the optical axis **82** and one another. If necessary, the primary optic body **564** may also be repositioned at this time.

Alignment of the two optic bodies **562** and **564** is a crucial aspect of this invention, since any decentration of images will be amplified by the high diopter power of the primary optic body **564**. Visual confirmation of alignment can be facilitated by providing the compensating optic body **562** with a diameter D_{CB} equal to the diameter D_{PB} of the primary optic body **564**.

In addition, the ILC **560** can be made less sensitive to decentration by increasing the diameter of the optic zone, that is the portion of the optic body which has corrective power, in one or both of the IOLs **561** and **563**. For instance, while the optic zones of prior art IOLs typically have a diameter in the range of about 3.5 mm to about 7 mm, the diameters of the optic zones D_{PZ} and D_{CZ} in IOLS **561** and **563**, respectively, should be in the high end of that range or even higher, i.e. preferably from 5 mm to 8 mm. Even more preferably, at least one of the optic zone diameters D_{PZ} or D_{CZ} should be in the range of about 6.5 mm to about 8 mm. Although, as mentioned previously, the diameters D_{PB} and D_{CB} of the optic bodies **562** and **564** are preferably equal, the diameters D_{PZ} and D_{CZ} of the optic zones need not be.

Another factor influencing centration is the flexibility of fixation member or members **568**. Preferably the member or members **568** are sufficiently flexible to allow the surgeon to reposition them as needed during the implantation process, but stiff enough to remain in a substantially fixed axial and radial position once implanted.

FIG. **6** illustrates a still further embodiment of an intraocular lens in accordance with the present invention. This intraocular lens, shown generally at **400** includes an optic body **401** and four (4) equally spaced apart movement members **403**. Each of the movement members **403** includes a distal region **405** and a proximal region **407** which is coupled to the optic body **401**. A hinge, for example, a linear hinge, such as a reduced thickness area **409**, is located near the proximal end **407** of each of the movement members **403**. A linear hinge is particularly advantageous to achieve enhanced, or even substantially maximum theoretical, axial movement.

The IOL **400** can be used in place of the various second optic/movement assembly subcombinations noted above. One distinction between IOL **400** and these other subcombinations is the use of four (4) individual movement members **403** which do not totally circumscribe the optic body **401** relative to the movement assemblies noted previously which fully circumscribe the second optics. It should be noted that the movement assemblies of the present ILCs can have other configurations, for example, which are effective to facilitate or even enhance the movement of the second optics.

While this invention has been described with respect to various specific examples and embodiments, it is to be understood that the invention is not limited thereto and that it can be variously practiced within the scope of the following claims.

What is claimed:

1. An accommodating intraocular lens having an optical axis, comprising:

an anterior optic having positive refractive power;

a posterior optic having negative refractive power;

an anterior biasing element comprised of an anterior distal end portion and a proximal portion, wherein the proximal portion is comprised of an area of reduced thickness which completely circumscribes the anterior optic and is configured to provide additional flexibility to the anterior biasing element; and

a posterior biasing element comprised of a posterior distal end portion;

wherein the anterior distal end portion and the posterior distal end portion intersect at a peripheral zone surrounding a portion of the optics as viewed from the anterior or posterior side;

wherein the peripheral zone has an outer surface for engaging a capsular bag, and wherein at least one corner is formed at the outer surface of the peripheral zone by the intersection of the anterior distal end portion and the posterior distal end portion.

2. The accommodating intraocular lens of claim **1**, wherein a radially inner surface of the anterior and posterior biasing elements is concave at an equatorial plane disposed between the anterior and the posterior optics such that the accommodating intraocular lens is configured to engage the capsular bag at the equatorial plane of the accommodating intraocular lens.

3. The accommodating intraocular lens of claim **1**, wherein the anterior biasing element extends radially outwardly from the anterior optic and defines a continuous periphery around the anterior optic.

4. The accommodating intraocular lens of claim **1**, wherein the anterior biasing element extends generally linearly from the anterior optic to the peripheral zone and the posterior biasing element extends generally linearly from the posterior optic to the peripheral zone.

5. The accommodating intraocular lens of claim **1**, wherein the anterior optic and the anterior biasing element are separate components from the posterior optic and the posterior biasing element.

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